ROCKY SHORES, SANDY BEACHES AND THE NEAR SHORE

Background

Formation and Characterization

Nearshore habitats are among the most bio-physically dynamic marine environments, being characterised by high vulnerability to anthropogenic and natural drivers. Worldwide, such habitats have been highly altered to meet the demand of growing populations, as well as for various subsistence and economic ends. The nearshore environment is generally defined as the area encompassing the transition from sub-tidal marine habitats to associated upland systems. They include the beach, the intertidal and subtidal zone, and the upland area of the shore. Depending on the type of substrate such habitats may either be rocky, sandy or muddy in nature, thus intertidal rocky shores, sandy beaches, muddy shores, mangroves, seagrass meadows and coral reefs tend to fall under this broad category (Maina 2015). While coral reefs, seagrass meadows and mangroves are addressed in separate parts of the outlook, this chapter will focus on the subtidal and intertidal rocky and sandy shore habitats.

The major difference between rocky and sandy shore habitats is the nature of the substrate, leading to fundamental differences in the biophysical characteristics of these equally important marine biotopes. Rocky shores are mostly formed as a result of denudation of the over-burden and bedrock caused by a combination of sea level rise and wave action in areas of limited sedimentation (Ruwa 1996). Rocky shore habitats can also be extended by the presence artificial coastal structures such as seawalls, groynes, dykes and jetties (Moschella and others, 2005). The physical properties of a given rocky shore is chiefly determined by the mode of its geological formation (Yorath and Nasmith 2001). Pleistocene limestone are the main geological formations in the WIO region, dominating the intertidal zone and the subtidal in Madagascar, northern Mozambique, Tanzania and Kenya, while aeolianite is common in the north-eastern and southern coasts of South Africa and Mozambique, respectively (Kalk 1995, Ramsay 1996). Some rocky shores in the WIO oceanic islands are granitic and basaltic in origin, with notable examples being the granitic reefs of Mahe, Seychelles (eg Hill and Currie 2007). Basaltic reefs are common in Mauritius and the Comoros. Some islands in the region comprise atolls, formed from coral and have limestone cliffs of interglacial origin. Aldabra Atoll in Seychelles is one such island (Ruwa 1996). Table 1 below summarizes some of the major rocky shore geological formations in the WIO region. However, like in most tropical marine waters in the western Indian Ocean most of such rocky shores are biogenic, being formed from raised fossil corals. Such reefs are therefore characterised by the presence of pits, cracks and crevices, creating extremely heterogeneous environments with numerous rock pools, overhangs, gullies and caves.

Physical attributes such as hardness and porosity vary significantly among different rock formations, with limestone and basaltic rocks being more porous than granitic ones. Such variation in physical properties invariably determine the nature of various biological processes such as larval settlement and recruitment, and thus nature of the climax benthic biological communities found on such habitats (UNEP/ Nairobi Convention Secretariat, 2009).

Table 1: Examples of rocky reef formations at selected locations in the WIO.

Location	Type of formation
Dar es Salaam (Tanzania)	Limestone (Hartnoll 1976)
Inhaca (Mozambique)	Sandstone (Kalk 1995)
Maputaland (South Africa)	Sandstone (Ramsay 1996)
Durban (South Africa)	Sandstone (Martin and Flemming 1988)
Seychelles	Coral rock, granite (Ngusaru 1997)
Mauritius	Basalt, limestone (Hartnoll 1976)
Kenya	Limestone (Ngusaru 1997)
Tulear (Madagascar)	Limestone (Hartnoll 1976)
Comoros	Basalt (Ngusaru 1997)
Northern Mombasa (Kenya)	Limestone (Ngusaru 1997)

Source: UNEP/Nairobi Convention Secretariat (2009).

While rocky shores often occur in areas of high wave energy, sandy shores are a characteristic of areas of high depositional activity, resulting into wave deposited accumulations of sediment on or close to the shoreline. For such habitats to form there must be: a basement (hard stratum), i.e. the bedrock, waves to shape them, sediment, and most in most cases also rivers and/or tides to bring the sediments on the foreshore (Short 2012). The beach extends from the wave base where waves begin to feel the bottom (and is about to break), and extends across the nearshore zone, through the intertidal area to the upper limit of wave swash, where the wave eventually breaks.

A major source of beaches in the WIO region is carbonate-sourced sediments, derived from either dead shells that have been transported to the shore from shallow marine environments (shelf sediments) or eroded from nearby shores and reefs and transported by long-shore currents (Fennessy and Green, 2015). However, in coastal areas drained by major rivers that discharge large amounts of sediments, the beach and nearshore would be dominated by sediments of terrigenous origin. Such sediments are geo-chemically characterized by the presence of quartz and feldspar minerals, and thus siliciclastic in nature. However, where these riverine clastic sediment inputs are small, biogenic (bioclastic) sedimentation, produced by erosion of the skeletal carbonate remains of marine organisms, can dominate. The distribution patterns of the various sediment textures (mud, sand, gravel etc.) vary according to proximity to river mouths, depth, wave action and currents (Nichols 2009), with the fine fractions (mud and fine sand) being the most easily dispersed. The type of sediment can thus change substantially along and across a shore depending on the relative contributions from carbonate and/or clastic sediment production (Fennessy and Green, 2015).

The amount and patterns and distribution of shelf sediments reaching the intertidal and nearshore is mainly determined by the bathymetric characteristics and hydrographic dynamics of the continental shelf. For instance, the location of the continental shelf break, which determines the width of the shelf, is a function of interaction between sedimentation processes, sea level changes and tectonics (sea floor emergence or submergence). In addition, reefs and submerged shorelines, for example, form barriers, allowing sediment to accumulate between them and the shore, partly helping to retain the sediments in the nearshore (eg Puga-Bernabéu and others, 2011). Since coral reef coverage in the WIO is minimal compared to the total estimated shelf area, it is obvious that the vast majority of the sea bed in the WIO comprises of unconsolidated sediments (Fennessy and Green, 2015), creating a reliable source for sediments essential for maintaining sandy shores.

Patterns of biological distributions

A common feature on most rocky shores is ability to support diverse assemblages of benthic organisms which exhibit peculiar distribution pertains. Such patterns are in response to a number of biophysical factors operating at different spatial and temporal scales (Menge and Sutherland, 1987). While variations at a bio-geographical level may be explained by such large-scale factors as large current systems and broad scale sea water temperature regimes (Bustamante and Branch, 1996), local variations in species composition are invariably a result of factors operating at smaller spatial scales. These include physical attributes such as extent of wave exposure, insolation, temperature, aspect and substratum type. The combined effect of such environmental attributes is the creation of unique zones of species distribution on most intertidal rocky shores (Stephenson and Stephenson, 1972). The following broad zones can therefore be distinguished on a typical intertidal rocky reef: the supra-littoral zone (littoral fringe), upper eulittoral zone and the lower eulittoral (sublittoral zone), with the most thermal tolerant species inhabiting the upper shores.

While patterns of species distribution on rocky shores are primarily determined by physico-chemical gradients along the shore height axis, the role of biological interactions is also important. For instance, processes such as competition, facilitation and predation are crucial in shaping the final assemblages of species in given biological communities (Steffani 2000, Coleman and others, 2006). One of the most notable examples of the influence of biological interactions on biotic patterns on rocky shores is the role played by such processes such as grazing and competition in setting species distributional limits in lower parts of the shores (Boaventura and others, 2002). Several ecological models have included biotic interactions as important determinants of the structure of biological communities. One of the classical examples of such models is by Menge and Sutherland (1976), predicting the comparative importance of predation in determining community composition in relatively benign environments, with competition being progressively more important as the environment becomes harsher. The model was however, modified to include the effects of recruitment variations (Menge and Sutherland 1987), mainly down-playing the importance of predation and competition in areas with low recruitments.

The predictable ability of gradients of physical and biological factors in determining patterns biological distributions on rocky shores may be made more complex by the presence of rock/tide pools. These important features of most rocky shores interrupt significantly enhance species abundance and richness in parts of the shore that would have supported less such abundances (Firth *et al*., 2013). This, invariably extends the distributional upper limits of many species, making the biological zonation less pronounced (Steffani 2000).

Figure 1: To insert Photo: rock pools in Inhaca, Mozambique

Unlike rocky shores where the substrate is mostly consolidated and stable, organisms on sandy shores need to be highly adapted to living on or within substrate that is unstable and constantly disturbed by swash, tides and wind (Janssen and Mulder, 2005). However, in contrast with rocky shores, atmospheric exposure and desiccation is not a major concern for sandy shore benthos, as they can retreat into the substratum or underneath the water table. Though tides disturb sandy shore benthos, most such organisms depend on the tides for feeding, as latter bring in suspended food particles on which many filter-feeders forage. To cope with tidal movements many species of meiofauna use vertical tidal migrations through the sand (McLachlan 1977; Steyaert and others, 2001), while other motile species move up and down the beach with the tides. The movement of the fauna along the shore axis is in response to various stimuli, which are both directional (such as light, slope of the beach, water currents) and non-directional (such as disturbance of the sand, changes in temperature, hydrostatic pressure. Dominant functional groups on many sandy shores are filter feeders and scavengers. As in other benthic marine benthic environments biotic distributions and abundance of sediment infauna is mostly controlled by complex interactions between the physicochemical and biological properties of the sediments (Knox 2001). These include grain size, water content, flushing rate of water through the sediment, oxidation-reduction state, dissolved oxygen, temperature, light, organic content, food availability and feeding activity, reproductive effects on dispersal and settlement, behavior that induces movement and aggregation, intraspecific competition, interspecific competition and competitive exclusion, and predation effects (see Rodriguez and others 2001; Moreno and others 2006).

Associated key species

Near shore habitats such as rocky shores and sandy beaches host a wide range of species, by offering a wide range of micro habitats and ecological niches. Such species are found to live in the habitats either permanently, spending part of their life cycles (Gibson and Yoshiyama, 1999) or simply using them as feeding grounds or refugia. Among important taxa on rocky shores are macroalgae. These are habitat-forming organisms with which other organisms associate (Casu and other, 2006). They also contribute significantly to the pelagic energy-biomass budgets by acting as a source of pelagic carbon. There are also a wide range of benthic invertebrate assemblages associated with rocky shores in the WIO region. These include molluscs (bivalves, gastropods and cephalopods) and crustaceans (e.g. Postaire and others, 2014). Besides, several commercial species of finfish have been found to be associated with rocky reefs (Durville and Chabanet, 2009; Maina 2015; Sindorf and others, 2015). They include a number of species belonging to families such as Moringidae, Muraenidae, Pseudochromidae, Kuhliidae, Lutjanidae, Chaetodontidae, Pomacentridae, Labridae, Mugilidae, Blenniidae, Gobiidae, Tripterygiidae, Acanthuridae, Bothidae, Sparidae, Carangidae (Durville and Chabanet, 2009; Maina 2015). The majority of these fish use rocky shores as nurseries and temporary refugia (e.g. during strandings)

Sandy beaches are famous for their recreational value. However, these habitats host considerable marine biodiversity, with diversity species of both invertebrates and vertebrates. Important taxa associated sandy shores in the WIO region include invertebrate infauna, dominated by interstitial meiofauna (eg Barnes and others, 2011). These form an important trophic compartment of the benthic food webs of sandy shores and adjacent habitats, by acting as a source of food for both benthic and pelagic consumers. Invertebrate macrofauna are also common on sandy shores, with various species of crabs and bivalves being abundant. One the most common such taxa are the ghost crabs, which are normally used as ecological indicators for ecosystem's health, as regards to the anthropogenic impacts on the beach. Apart from being rich in invertebrate fauna, sandy shores of the WIO region are ecologically important for certain vertebrate taxa. Sea turtles are such taxa, whereby sandy beaches play an important role in support their life histories. Along several coastlines in the region sandy shores act as important nesting areas for several species of marine areas, where periodically adult female turtles return on the beach to lay eggs. Five species of sea turtles have been documented in the Western Indian Ocean (Marquez 1990, Ratsimbazafy 2003, Seminoff 2004). Of these, the green turtle (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) are most widely distributed and most numerous. Loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) used to be abundant along the South African waters, but less common in the rest of the region. Relatively little has been documented about the olive ridley (*Lepidochelys olivacea*) (Bourjea and others, 2008). All the species are CITES protected. Besides, hawksbill and green turtle are listed as Critically Endangered and Endangered on the IUCN red-list, respectively. The rest are listed as Vulnerable (www.iucnredlist.org. Downloaded on 03 October 2018). Table 2 shows the nesting species of sea turtles as recorded per each WIO country.

Table 2: Nesting status for species of sea turtles in the WIO countries (Modified from: Bourjea and others, 2008)

Country	*Chelonia mydas*	*Caretta caretta*	*Dermochelys coriacea*	*Eretmochelys imbricata*	*Lepidochelys olivacea*
Kenya	Nesting	Sighting	Sighting	Nesting	Rare nesting
Madagascar	Possible nesting	Possible nesting	Sighting	Possible nesting	Possible nesting
Mauritius	Possible nesting outer islands	-	-	Possible nesting outer island	-
Mozambique	Nesting	Nesting	Nesting	-	-
Reunion/Eparses Island/Mayotte	Nesting	Very rare sighting	Very rare sighting	Nesting	Very rare sighting
South Africa	In water sighting	Nesting	Nesting	In water sighting	Rare
Tanzania	Nesting	In water sighting	In water sighting	Nesting	Rare nesting

Figure 2: Green turtle nesting in Mafia Island (Photo by: Sea Sense)

Regional coverage

Rocky shores and sandy beaches are one of the most common features along coastlines of the WIO countries. Information on the spatial extent and total areal coverage of such habitats in the region is scanty. However, estimates for the whole Indian coast is put at 3000 km^2, excluding the western Australian coast (Wafar 2001). This has been computed as a product of the total coastline lengths of all maritime states of the Indian Ocean (66,000 km) and an average intertidal width of 50 m (Qasim 1998).

Figure 3: To insert: Map of the Western Indian Ocean region coastline length showing segments covered by rocky shore and sandy beaches

Ecological and Socio-economic Importance

Intertidal and nearshore habitats offer considerable benefits, in terms of their ecological and socio-economic values. Both in isolation, and as part of the wider seascape, such habitats contribute significantly to marine productivity, ecological integrity, as well as local livelihoods and economies.

Ecological importance

Rocky shores sandy beaches are important habitats for several marine species. Being highly complex habitats, with high topographic heterogeneity, create a multitude of microhabitats and niches for diverse groups of benthic organisms other associated species (Kostylev and others, 2005). Although stable over ecological temporal scales, topographic heterogeneity is crucial in influencing spatial structure of environmental variables and in turn, biological processes during both low and high tide. For instance, by creating desiccation stress gradients, through the regulation of immersion periods, topographic heterogeneity on rocky shore provides refuges against desiccation as well as competition and predation (Sebens 1991). Besides, the increased substrate heterogeneity conferred by topographic features such as crevices, cracks and rock boulders protect many mobile animals against thermal stress by providing shade (Williams and Morritt, 1995). Such topographic heterogeneity attracts high diversity of benthic fauna, with almost all invertebrate phyla being represented (Deepananda and Macusi, 2012). Although sandy beaches have more unstable substrate compared to rocky shores, organisms on such habitats have been highly adapted to withstanding the impact physical perturbation characteristics of such habitats. Therefore, sandy shores are home to abundances of burrowing macrofauna such crabs and bivalves, and interstitial invertebrate infauna, with the most important taxa being the meiofauna. These create an important part of the food web base for benthic ad pelagic systems (Barnes and others, 2011).

Rocky and sandy shore habitats have high ecological connectivity with other intertidal and nearshore habitats, contributing to the productivity of the latter. For instance, one of the common features of are rocky shores in the presence, micro and macroalgae. These abundant plants contribute significantly to marine productivity in support of marine food webs (Branch and others, 2008). For instance, macroalgae are highly productive, and act as a major source of organic matter in the marine environment (Worm and Lotze, 2006). Together with seagrasses, macroalgae are estimated to account for up to 40 percent of primary productivity in the coastal zone (Charpy-Roubaud and Sournia, 1990) and contribute significantly to the global marine plant biomass. Besides, such macrophytes fulfil crucial ecological functions in marine environment, including carbon storage and nutrient cycling (Worm and others, 2000). The interaction between rocky shores and sandy beaches with other marine ecosystems also ensures a constant interchange of biomass and energy within the marine environment (Menge and others,1997). For instance, the reproductive histories of most invertebrates on such habitats involve the production of large quantities of eggs and pelagic larvae. These create an important source of food for juvenile fish and other marine animals, thus enhancing fisheries production.

Rocky reef and sandy beaches are also important areas for spawning, nursing, foraging and nesting for various marine species. For instance, the presence of tide pools on most intertidal rocky shores offers an opportunity for several marine species to withstand the extreme environmental conditions observed in intertidal habitats during low tide (Sindorf and others, 2015). While tide pools can save some stranded reef fish and other visiting pelagic fauna during low tide, such pools may also act as temporary residences for several species, using the habitat during specific seasons or life history stages (Gibson and Yoshiyama, 1999). These include larval or juvenile fish recruits which leave the pools once they reach a certain body size or maturity stage. This makes the intertidal rocky shores one of the important nurseries for ecologically and commercially important deep-water species in several locations (Cunha and others, 2008), capable of replenishing surrounding reef populations and nearshore waters (Mahon and Mahon, 1994). A study by Sindorf and others (2015) on one of the intertidal rocky shores of the WIO demonstrated the importance of such habitats as nursery areas for reef-associated and deeper water fish populations. For instance, in the study, it was indicated that over half of the fish observed in the tide pools were juveniles, confirming that such habitats are used as nurseries. In the same study several other species were found to be residents of the area, with ten of such species being found in no other habitat in the surrounding area (Sindorf and others, 2015). Several other studies in the WIO have depicted the similar patterns (see Durville and others, 2003; Durville and Chabanet, 2009). Apart from rocky shores, sandy beaches are also play important roles in supporting the life histories of several marine species, with marine turtles being the most notable example. Five species of marine turtles have been recorded in the WIO, with four being confirmed to nest on the sandy beaches of the region (Bourjea and others, 2008).

In most areas in the WIO, rocky shores and sandy beaches serve as important feeding and foraging grounds for both terrestrial and marine animals. During low tides for instance, flocks of foraging sea birds are a common scene on most intertidal and nearshore while during high tide marine animals such fish also feed on benthic invertebrates and plants (Worm and others, 2000).

Figure 4: Sea birds on one of the rocky shores in southern Tanzania (Cecile Caihol)

Socio-economic importance

Apart from their ecological importance, nearshore habitats such as rocky shores and sandy beaches have considerable contribution to coastal livelihoods and economies. Sandy beaches are a major attraction on which coastal tourism is based. Several places across the WIO region are famous for their white sandy beaches and crystal-clear waters attracting thousands of tourists every, in turn supporting local and nation economies the region. Rocky reefs form natural sea defences on several coastlines, in so doing protecting valuable investments such as residential and commercial properties and associated infrastructure. By contributing to nearshore and pelagic productivity (Raffaelli and Hawkins, 1996) and acting as refugia and nursery grounds for some reef and deep-water fish (Durville and Chabanet, 2009; Sindorf and others, 2015), nearshore habitats play a significant role in supporting artisanal and commercial fisheries in the inshore waters, thus contributing to dietary needs, food security and incomes for local communities and beyond.

Subsistence gleaning for invertebrate resources is also wide a spread along the coastlines in the region (Kyle and others, 1997). Various types whelks, mussels, oysters, cockles, abalones, crabs, octopuses, barnacles, sponges and echinoderms being widely collected for food and income generation. Fishing activities are also common in many rock pools and shallow intertidal lagoons. Although practiced in limited scale, farming of several invertebrate species is also common in certain parts of the region. These include stalked barnacles, abalones, sponges and certain species of oysters (e.g. Troelli and others, 2006). Besides traditional subsistence gleaning activities on the intertidal and nearshore habitats, such habitats and associated species are supporting emerging commercial activities in the region. These include marine based ornamental (curio) trade, as well as sea weed, sponge, finfish cage and half pearl farming (Gössling and others, 2004; Branch and others, 2008; Gibbons and Remaneva, 2011)

Figure 5: Gleaning for shellfish on one of the rocky shores in Zanzibar (Photo by Daudi J. Msangameno)

Threats to Rocky shores, Sandy Beaches and Nearshore Habitats

There several phenomena and activities threatening the ability of nearshore habitats such as rocky shores and sandy beaches in the WIO region to support ecological productivity, integrity and by extension, livelihoods and economies. Although many of these habitats have the ability to adapt to high levels of natural environmental stress, such ability is threatened by various human-related activities.

Resource over-exploitation and physical disturbances

Most intertidal and nearshore habitats provide for highly accessible platforms from which resources can be harvested a low cost. During low tide, such habitats are typically visited by numerous people, gleaning for shellfish and other organisms, putting enormous pressure on the resources. Overharvesting may have profound impact on the functioning and integrity of the many intertidal ecosystems, not only in terms of the direct effects on populations of the targeted species but also in terms of habitat destruction and recruitment failure. Modifications of the benthic community composition through species overexploitation have been reported in the region. For instance, Siegfried (1994) reports on transformation of a filter feeder-dominated habitat into community dominated by coralline algae, due to over-exploitation of intertidal invertebrates by subsistence collectors. The impact of over-exploitation of invertebrate resources becomes more pronounced if the targeted organisms are keystone species (Little and Kitching, 1996) as such organisms play important roles in supporting other species within the ecosystems (Lindberg and others, 1998).

Apart from excessive harvesting of resources, human visitation on the intertidal can cause significant physical disturbance on the benthic biological communities, as human trampling may lead to changes in species composition (Casu and others, 2006). This can be either due to the direct physical impact, leading to dislodgement, mortality and general structural deformation of the organisms or indirectly, by causing loss in physiological efficiency, such as reproductive potential or competitive ability against other species (Denis 2003).

Pollution

Being mostly intertidal or shallow-water habitats, rocky and sandy shores are affected by both sea-borne and land-based activities. Pollution have serious impact on biological communities on such shores. For instance, excessive input of nutrients, silt, pesticides, heavy metals and debris into marine have been demonstrated to have adverse effects on biological on ecosystems (Crowe and others, 2000). Table 3 summarizes the potential impact of some of the major types of pollution on the rocky shores. This may also apply to other nearshore habitats such as sandy beaches.

Table 3: Major types of marine pollution and their impacts.

Type of Pollution	**Sources**	**Impacts**
Eutrophication	• Natural sources e.g. animal droppings (Bosman and Hockey, 1988) • Sewage outfalls and agricultural run-off (Clark and others, 1997)	• Transformation of stable benthic communities, e.g. replacement of perennial macroalgae by ephemeral algae, diatoms and cyanobacteria (Schramm, 1996)
Siltation	• River discharge, shore erosion, sediment re-suspension, and atmospheric transport (Airoldi, 2003) • Industrial and domestic discharges (Kim and others, 1998) • Mining, construction and dredging (MacDonald and others, 1997 • Aquaculture (Holmer *et al.*, 2001).	• Reduced species abundance (Saiz-Salinas and Urdangarin 1994) • Transformation of certain biological assemblages (Branch *et al.*, 1990) • Effects on larval settlement, recruitment, growth and survival (Airoldi, 2003).
Oil pollution	• Oil spills (Watt and others,1993)	• Partial or complete loss of macrobenthic diversity (Jones and others, 1996)
Heavy metal pollution	• Denudation of ore-containing rocks and volcanism (Clark *et al.,* 1997) • Domestic and industrial discharge and urban run-off (Anderlini, 1992; Clark and others, 1997)	• Reduced benthic growth e.g. in mussels and fucoid algae (Munda and Hudnik, 1986) • Effects on larval development (Fichet and others, 1998).

Source: Msangameno (2015)

Coastal development and urbanization

Coastal development and urbanization, if not well managed may have deleterious effect on shoreline habitats. Growth of urban areas along the coast and the associated activities leading to the use and conversion of coastal land have been having negative impact on marine biodiversity in the WIO (Celliers and and Ntombela, 2015). Poorly planned and uncoordinated development in most coastal urban centres have resulted into inadequate management of the coastal zone (Fraschetti and others, 2011), with significant implications to the marine ecosystems such as rocky shores and sandy beaches

For instance, in many areas along the coast, construction and infrastructure development have led to increased coastal erosion and water turbidity, affecting certain sessile communities. Moreover, the construction of certain defensive structures for shoreline protection (e.g. seawalls) interferes with key hydrographic and biological processes essential to maintenance of the integrity of such ecosystems (Branch and others, 2008; Bertasi and others, 2009), by interrupting the supply of recrui ts, nutrients and food. Such improper beach armoring can exacerbate beach erosion and turtle nesting habitats, block access by nesting turtles and fatally entrap turtles (Eckert and others, 1999). Likewise, another threat to sandy shore habitats is sand mining, with the persistent removal of beach sand disrupting stabilizing vegetation, also exacerbating beach erosion.

Climate change

It is no longer a debate whether global climate is changing. The global average temperature is now about 0.85°C above the pre-industrial range. Also, over the past 100 years, global sea level has risen by an average of 1-2 mm yr^{-1}, and scientists anticipate that this rate will accelerate during the next few decades (IPCC, 2014). Global climate change is seriously impacting the ecological systems in marine waters worldwide, with sea level rise and increases sea surface temperature being regarded as some of the most important aspects of that changes along the coast (Tsyban *et al*., 1990).

Climate change is predicted to drive significant shifts in the structure of biological communities (Helmuth *et al.*, 2006; Hawkins *et al.*, 2009), with recent climatic events already affecting the survival, development, phenology, physiology and ecology of a wide range of species within marine ecosystems (Walther *et al.*, 2002). Potential impacts of climate change on the intertidal habitats of the WIO are summarized in Table 3 below, being modelled around the potential environmental alterations to be caused by various climate-related stressors such as increased sea surface temperature, increased irradiation, sea level rise and changes in the patterns of atmospheric and oceanographic processes (Steffani, 2000).

Table 3: Potential impacts of global climate change on the rocky reef ecosystems

Climate related phenomenon	Ecosystem impact
Increased temperature	• Changes in biological composition in favour of more heat-resistant organisms (Barry *et al.*, 1995, Steffani 2000) • Effects on trophic interactions within benthic biological communities (Sanford, 1999) • Polar-ward shifts in genetic range shifts for certain species (Ling *et al.*, 2009) • Local extinction of certain species (Helmuth *et al.*, 2002).
Sea level rise	• Submergence and loss of benthic biological assemblages, especially on flat reefs and wave-cut platforms (Steffani, 2000)

Climate related phenomenon	Ecosystem impact
	• Upward displacement of benthic organisms on gentle sloping shores (Jackson and McIlvenny, 2011).
Ocean acidification	• Reduced calcification in calcareous benthos e.g. certain species of crustaceans, molluscs, echinoderms and coralline algae • Impairment of physiological and developmental processes in many benthic species, especially in the early life history stages (Gaylord and others, 2011) • Shifts in the community structure, dynamics and productivity
Changes in oceanic and nearshore circulations	• Changes in rates of settlement and recruitment of benthic organisms • Changes in patterns of biotic interactions such as predation, herbivory and competition (Menge and Sutherland, 1987) • Reduced productivity due to possible changes in patterns of nutrient and plankton supply (Menge and others, 1997)
Increased intensity and frequency of storms	• Reduced natural succession or recovery in benthic communities • Reduced habitat heterogeneity and species diversity (Sousa, 1985) • Community transformation e.g. reduced abundance of perennial species in favour of short-lived, fast-growing ephemeral species (Steffani 2000).
Increased coastal erosion and changes in sediment dynamics	• Loss of sand-intolerant species; increased dominance by sand-tolerant species; thus, reduced diversity within benthic communities (Menge and others 1983).

Source: Msangameno (2015)

Conservation Status and Level of Threat

Conservation status

Despite their considerable socio-economic and ecological importance, rocky shores in the WIO have received relatively little attention. Many intertidal habitats in the region, rocky shores are generally understudied, and undermanaged, with poor or no monitoring (Nordlund and others, 2014; Maina 2015). Therefore, apart from their known goods and services in support of livelihoods, little is known of the quantifiable status of the resources on such habitats, as well as their generalized level of conservation status. This can be attributed to the general lack of a dedicated comprehensive, multispecies region-wide assessments made on such habitats.

However, it must be appreciated that the conservation status of rocky and sandy shores habitats can be site- specific, with such statuses varying across different geographical settings and jurisdictions. This could be mainly due to geographical variations in the levels of direct threats to such habitats, as specified in IUCN-CMP Unified Classification Scheme (Version.

3.2) and as in the detailed assessment made in the subsequent section of this chapter. Although, constantly under higher anthropogenic pressure, near shore habitats in the WIO can be generally considered ‘vulnerable’ at worst (refer IUCN Conservation status categories). As far as the IUCN Threat Impact Scoring System (IUCN, 2012) the threat of near shore habitats such ad rocky and sandy shores can putatively, be judged to be continuing, with slow severity and affecting the majority of the habitats in the region, thus the threats are of medium impact.

Assessing current levels of threat

Although several observations in the region, reveal continued support of the rocky shores and sandy beaches for the sustainable exploitation of their resources (Msangameno, 2015), sustained pressures in the form of over-harvesting, habitat alterations, pollution and possibly climate change, may have serious impact on the ability such ecosystems to offer the vital goods and services. A comprehensive prognosis for the future of rocky reef habitats was given by Branch and others (2008), in which a wide range of impacts are predicted at all ecological levels (individual, populations and communities). Although many of these impacts are predicted to be localized, such as point pollution sources and local human resource exploitation, they are projected to affect entire coastlines if unchecked, leading to widespread changes in primary and secondary productivity, with consequences for both commercial and unexploited species, together with associated ecosystem goods and services (Branch and others 2008).

However, it has to be appreciated that the ability to predict the consequences of changes in a single impact may vary from reasonable certainty to considerable uncertainty, for example in terms of ecosystem responses to changes in global climate or the introduction of non-native species (Thompson and others, 2002). As the ability to forecast the interactive effects of several environmental factors is at best fairly modest, unpleasant surprises can be expected in the future (Branch and others, 2008). This will happen where environmental change induces shifts between alternate states (Paine and others, 1998); an organism is particularly susceptible to a pollutant; or an exotic species has a much more prominent role in an invaded community than at home (Branch and others, 2008).

Existing Protection Levels

To safeguard the provision of ecosystem goods and services by marine ecosystems there need to be deliberate actions to protect such ecosystems against a number of anthropogenic stressors. Various forms of marine habitat protection exist in the WIO, with considerable successes. There are seldom any exclusive measures for the protection of rocky reef habitats and sandy shores in the region in the same level accorded to such ‘key stone’ ecosystems as coral reefs and mangroves. However, some of such near shore habitats tend to fall within the broader realms of the existing area-based protection mechanisms such as Marine Protected Area (MPAs) and Locally Managed Marine Areas (LMMAs).

Currently there are over 137 MPAs (Sistika pers. comm.) in the WIO region. This is on top of 11,000 square kilometres being protected under various LMMAs arrangements (Rocliffe and others 2014). By assisting in regulating levels of resource harvesting, and improving rates of recruitments, growth and survivorships of various benthic species, these area-based measures have been proved to effective in maintaining or even improving biological abundances, diversity and endemism on rocky shores and similar habitats, as has been shown in certain parts of the WIO (see McClanahan 1989; Postaire and others, 2014). Despite their usefulness MPAs and LMMAs will only offer effective protection of such ecosystems and their resources, if their spatial coverage becomes large enough to include the majority of the such habitats. Currently, the protection level of rocky reef habitats in the region can at best be described as poor (<30 percent).

Priority Options for Conservation

Since only a fraction of the rocky reef habitats in the WIO is under any form of formal protection, there are considerable opportunities for improving their protection levels to 20 percent of total areal extent. Although there is no definitive figure of the areal extent of rocky shores in the region, one of the best options for prioritizing and increasing such spatial coverage would be the incorporation additional areas into the existing MPAs and LMMAs within each national jurisdiction. To assist in the identification of such additional areas assessments can be undertaken to measure the level of their ecological potentials, based on measurable criteria such as those used to designate the Ecologically or Biologically Significant Areas (EBSA) (CBD Secretariat 2008). These are areas meeting at least one of the following criteria of: ecological uniqueness of rareness; special importance for life history stages of species; importance for threatened, endangered or declining species and/or habitats; vulnerability, fragility, sensitivity, or slow recovery; biological productivity; biological diversity; or naturalness (Dunn and others 2014). There are 39 marine EBSAs identified in the WIO region, and these can be used as the basis for increasing areal coverage by putting rocky reef, sandy beaches and other nearshore habitats under formal protection.

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